

CHAPTER SEVEN

Differentials and Drive Axles Classroom and Shop Manual

Objectives

- Describe the purpose of a differential.
- Identify the major components of a differential and explain their purpose.
- Describe the various gears in a differential assembly and state their purpose.
- Describe the various methods used to mount and support the drive pinion shaft and gear.

Objectives (*cont'd*)

- Explain the need for drive pinion bearing preload.
- Describe the difference between hunting, non-hunting and partial non-hunting gear sets.
- Explain the purpose of the major bearings within a differential assembly.
- Describe the operation of a limited-slip differential.

Objectives (*cont'd*)

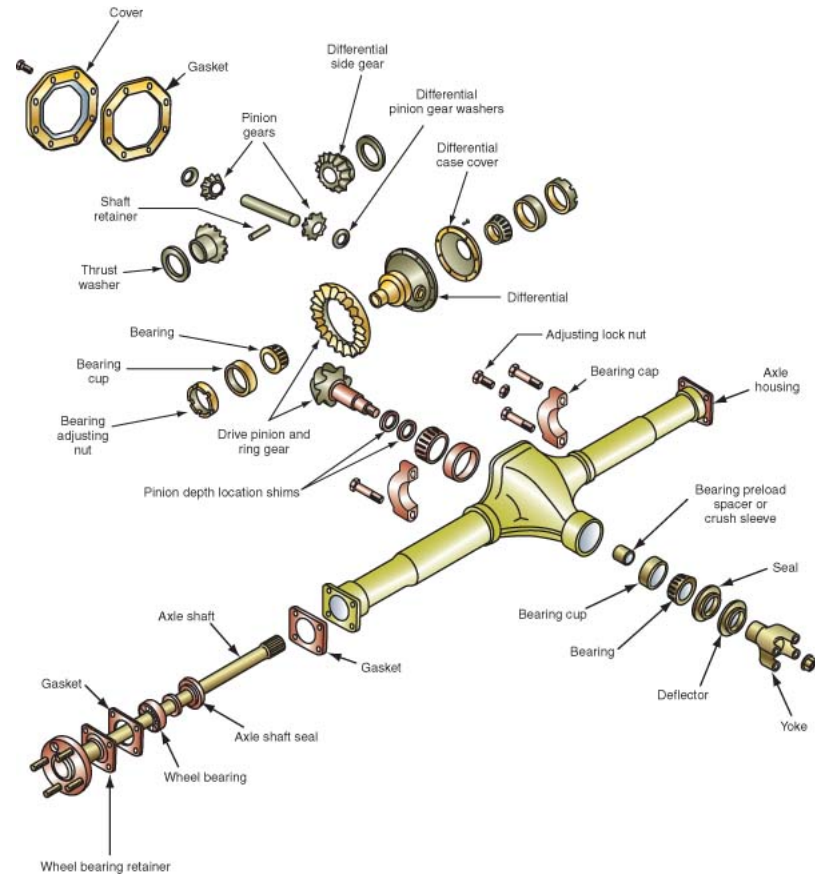
- Describe the construction and operation of a rear axle assembly.
- Identify and explain the operation of the two major designs of rear axle housing.
- Explain the operation of a FWD differential and its drive axles.
- Describe the different types of drive axles and the bearings used to support each of them.

Purposes of a Drive Axle Assembly

- To transmit power from the drive shaft to the wheels
- To turn the power flow 90 degrees on RWD cars
- To allow the wheels to turn at different speeds while cornering

RWD Live Axle Components

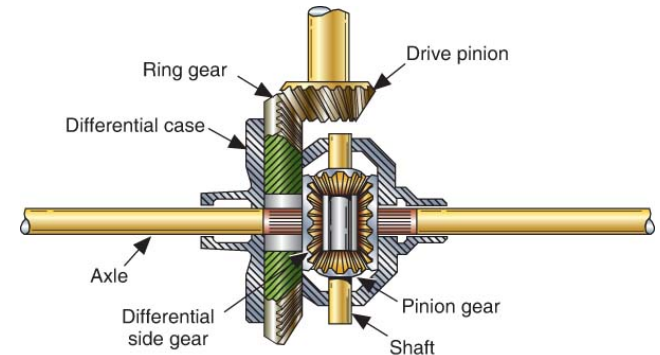
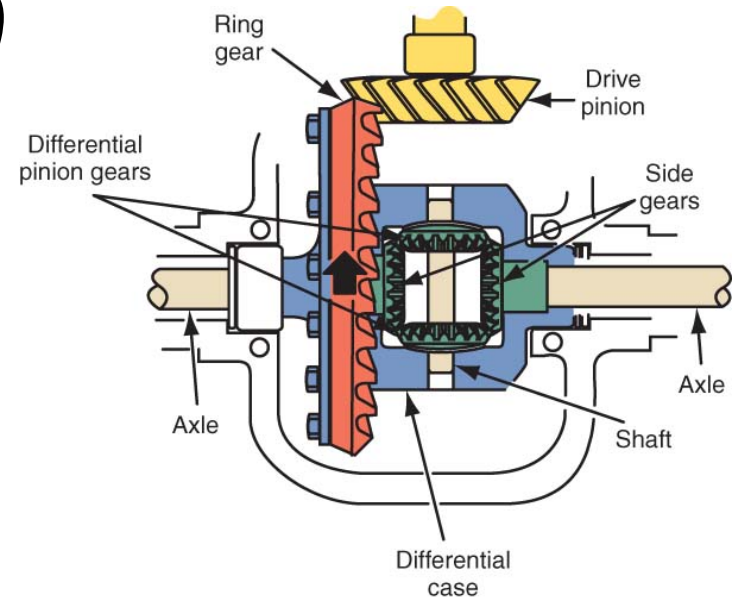
- Rear axle housing
 - Holds all other components and attaches to the vehicle's suspension
- Ring and pinion gears
 - Provide a final gear reduction
 - Transfer power 90 degrees to the wheels



RWD Live Axle Components

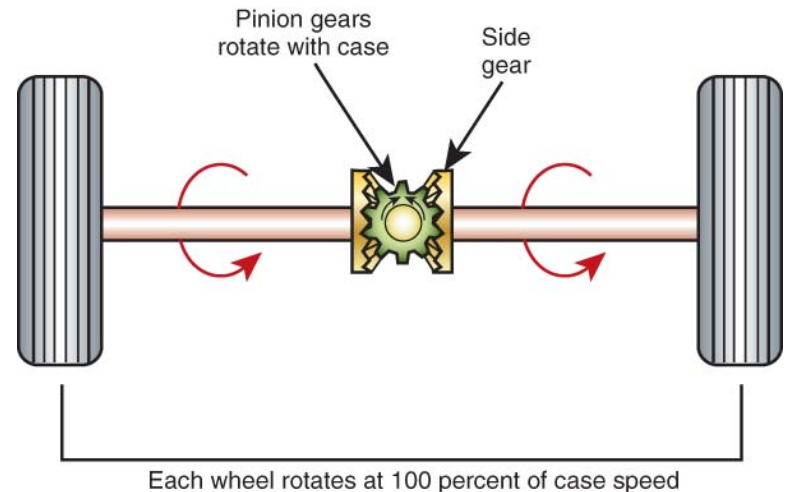
(cont'd)

- Differential assembly
 - Contains the differential case which attaches to the ring gear
 - Includes the side gears and differential pinion gears that allow wheels to turn at different speeds
- Axles
 - Transmit power from the differential to the wheels



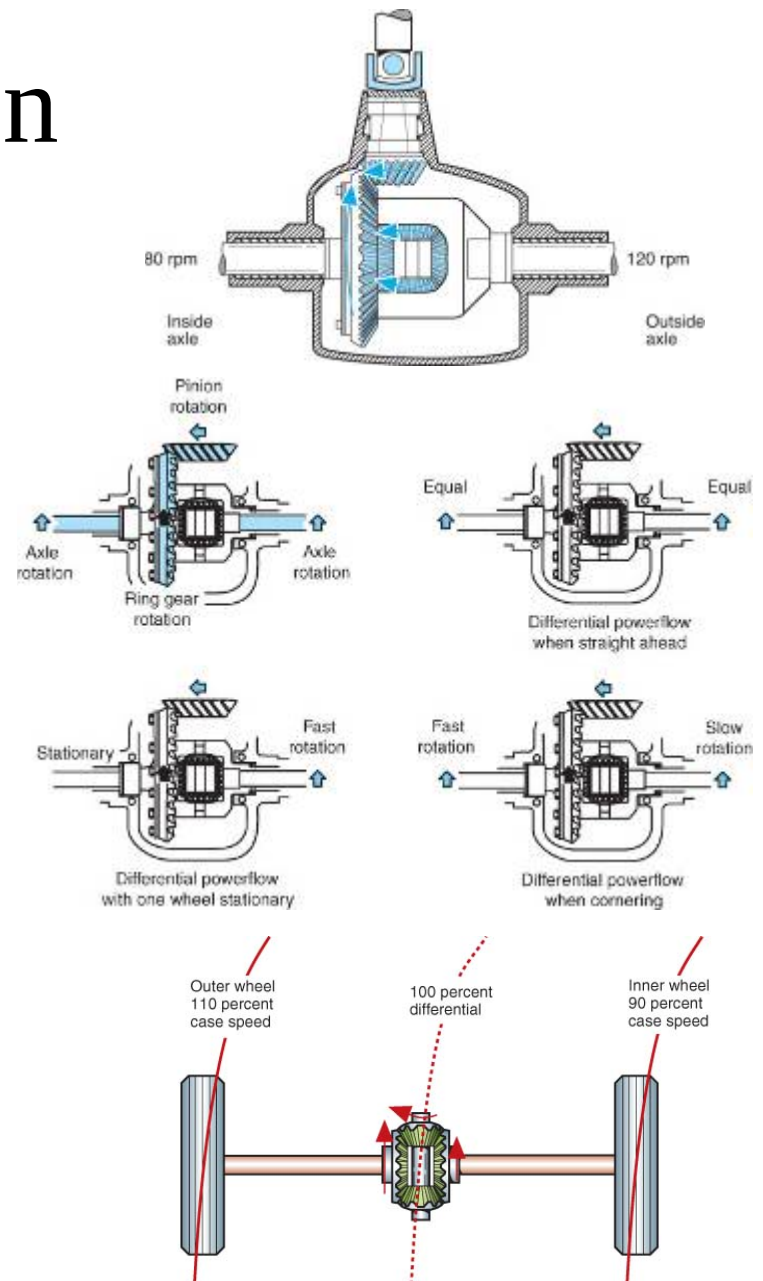
Differential Operation

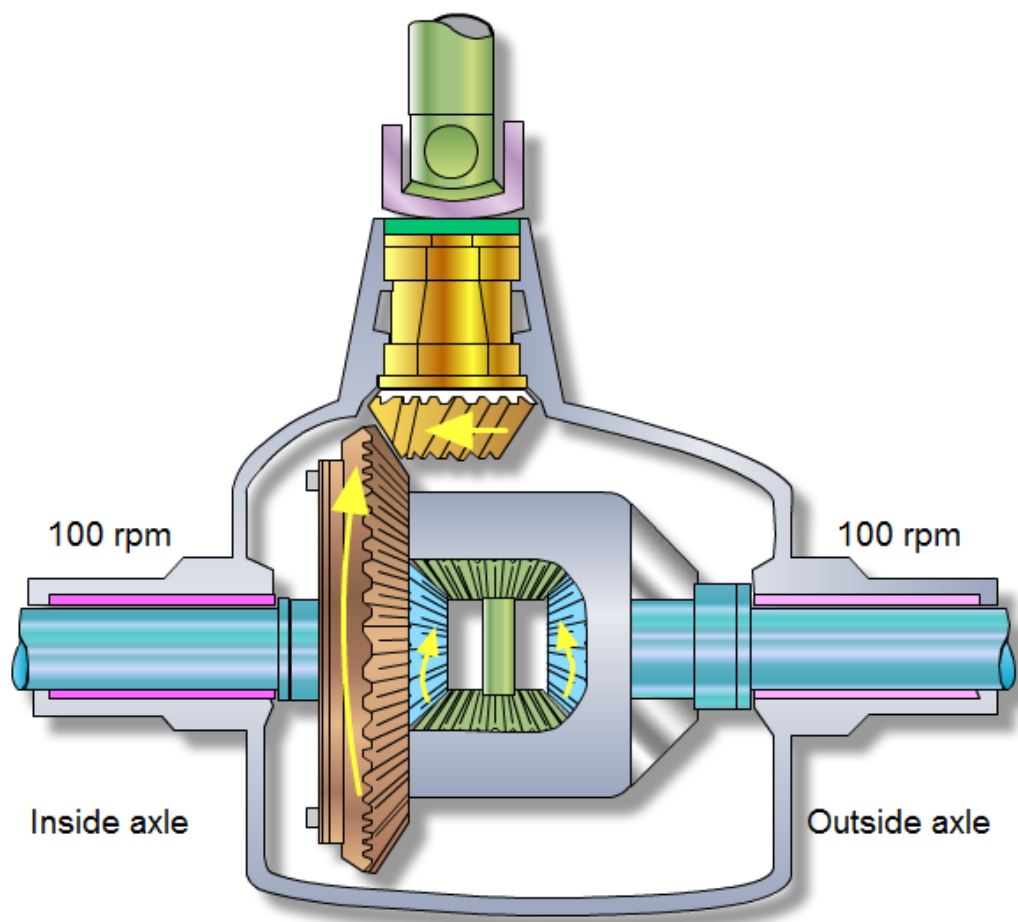
- The drive pinion drives the ring gear which is attached to the differential case
- When going straight ahead:
 - The differential housing and its components rotate as an assembly
 - Power is transferred equally to both wheels



Differential Operation (*cont'd*)

- When turning a corner:
 - The wheels must travel at different speeds to prevent tire scrubbing
 - Differential pinion gears “walk” around slower side gear and cause other side gear to turn faster
 - The percentage of speed that is removed from one wheel is given to the other

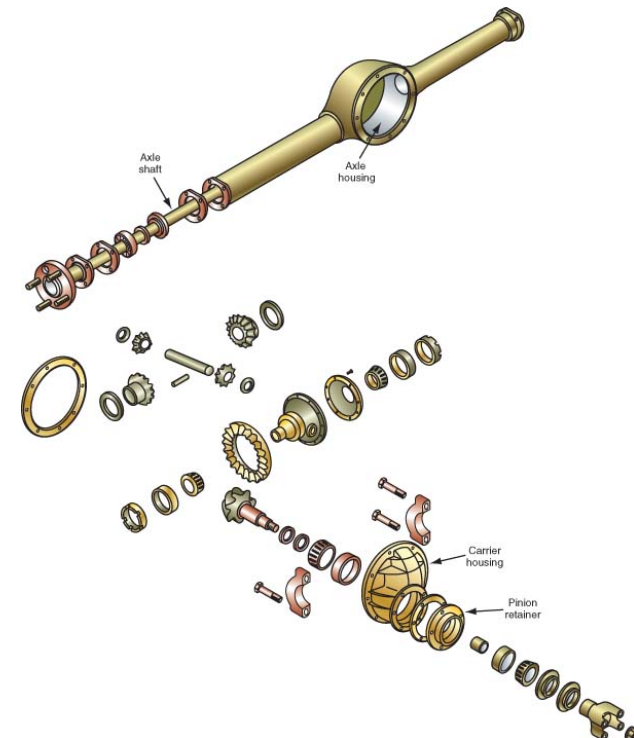
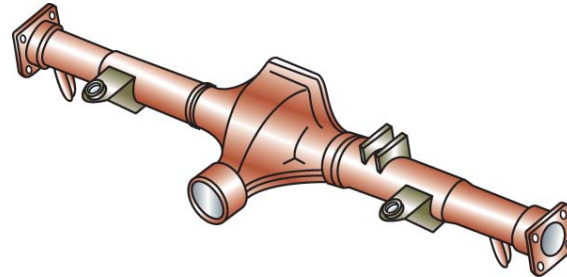




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Types of Axle Housings

- Integral carrier type
 - The differential assembly is mounted in and supported by the axle housing
 - It is sometimes called a Salisbury-type
- Removable carrier type
 - The differential assembly can be removed from the axle housing as a unit
 - It is sometimes called a pumpkin-type

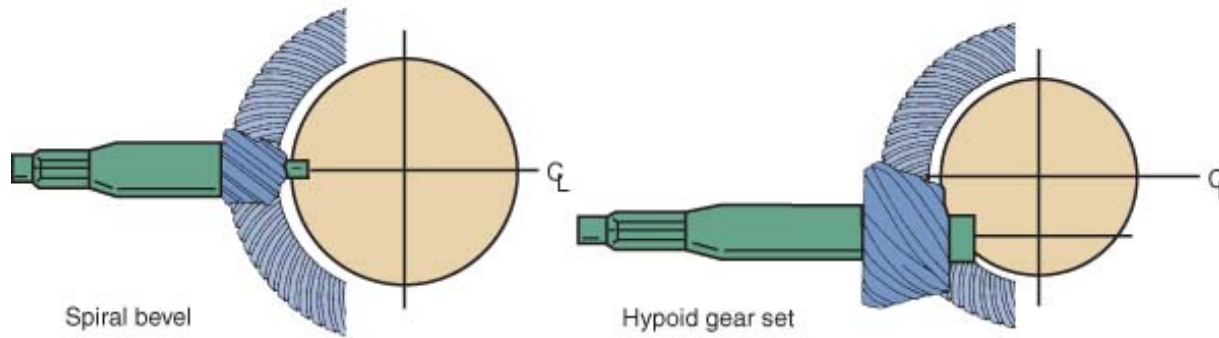


Differential Gears

- Two types of gears as RWD differential gears; spiral bevel and hypoid
- Spiral bevel gears are commonly used in heavy duty applications and are noisier than hypoid
- Hypoid gear sets are commonly used in RWD passenger car and light truck applications

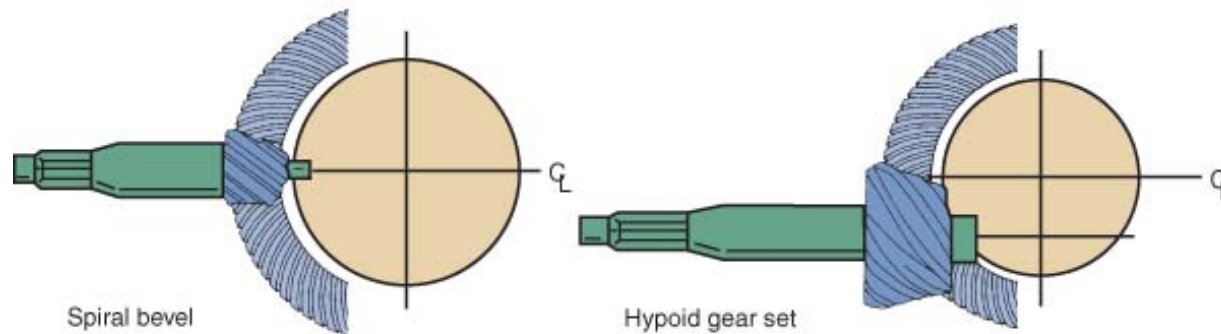
Spiral Bevel Gears

- The centerline of the drive pinion intersects the centerline of the ring gear
- They are usually used in heavy-duty truck applications
- They are usually noisier than hypoid gears



Hypoid Gears

- The centerline of the drive pinion gear intersects the ring gear at a point lower than the centerline
- They are commonly used in cars and light-duty trucks
- Their design allows for a lower vehicle height and more passenger room inside the vehicle



Gear Ratios

- The overall gear ratio is equal to the ratio of the ring and pinion gears multiplied by the ratio of the gear the transmission is in
- Numerically low gears are said to be “high”

Gear Ratios (*cont'd*)

- Numerically high gears are said to be “low”
- Gear ratios are usually selected to provide the best combination of performance and economy

Calculating Overall Gear Ratios

If the transmission gear ratio is: 1.5:1

And the final drive gear ratio is: 3:1

The total final drive ratio is: 4.5:1

$$1.5 \times 3 = 4.5$$

3 Ways to Determine Final Drive Ratio

- Using the vehicle service manual, decipher the code on the tag attached to or stamped on the axle housing
- Compare the number of revolutions of the drive wheels with those of the drive shaft
- Count the number of teeth on the drive pinion gear and the ring gear

Plant code

V033A
3 08 88 4F22

MFD. By :

Date: 09/92 GVWR: 5345 - 2425 KG
Front GAWR: 2713 LB. Rear GAWR: 2682 LB
1231 KG 1215 KG

Vehicle conforms to all applicable federal motor vehicle safety and bumper standards on the date of manufacture shown above.

Veh. Ident No. 1FABP43H9GH052068
Type: Passenger
3H
Exterior paint colors

Body	VR	MLDG	INT TRIM	A/C	R	S	AX	TR
53H	HD	G6D	DD	A	2	B	G	xxxxB

Axle code Ratio

8(M*)	2:73:1
G	2:26:1
Y(Z*)	3:08:1
F(R*)	3:45:1
B	2:47:1

* Traction-Lok

Axle ID code

Rear cover shape

7 5/8 " Ring gear 8 1/2 " Ring gear

Axle front view

2 AB G 125 1

1 2 3 4

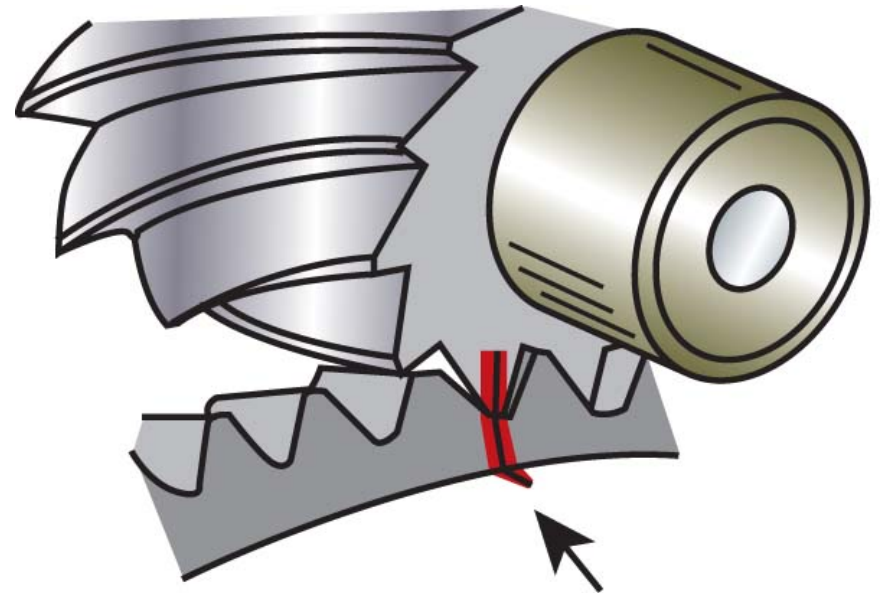
1 Axle code
2 Manufacturer
K-GM of Canada
G- Saginaw/Detroit
3 Build date
4 Shift
1-Day
2-Night

Typical code tag

2 AB G
125 1

Gearset Classifications

- Nonhunting gearset
 - Each tooth of the pinion gear will come in contact with the same teeth on the ring gear each revolution
 - The gearset must be assembled with its index marks aligned
 - An example ratio is 3.0:1



Paint marking indicates position in which gears were lapped

Gearset Classifications (*cont'd*)

- Partial nonhunting gearset
 - Any one tooth of the pinion gear will come in contact with some of the teeth on the ring gear each revolution
 - The gearset must be assembled with its index marks aligned
 - An example ratio is 3.5:1

Gearset Classifications (*cont'd*)

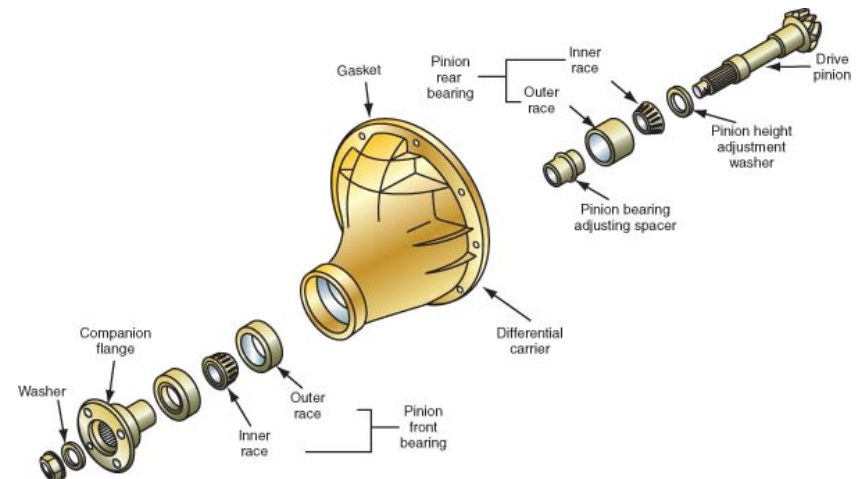
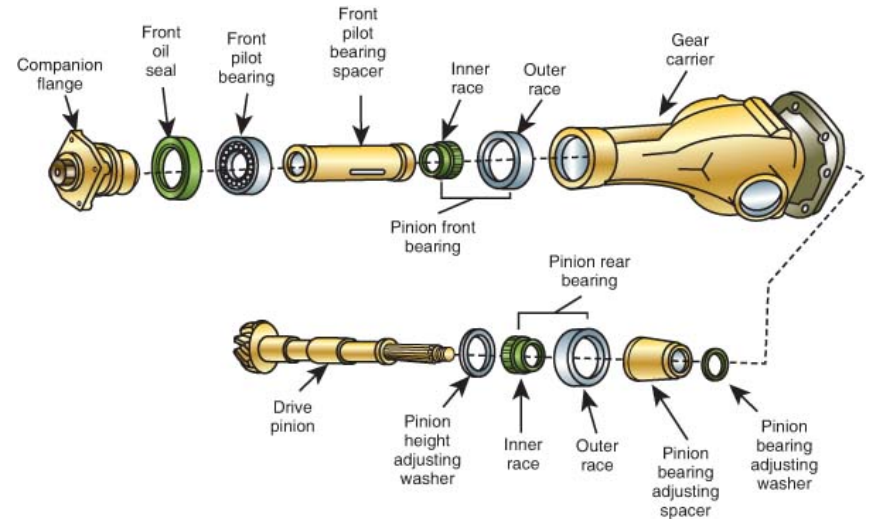
- Hunting gearset
 - Any given tooth on the pinion gear contacts all of the teeth on the ring gear before it meets the same tooth again
 - The gearset does not have to be indexed
 - An example ratio is 3.73:1

Differential Bearings

- At least four bearings are found in all differentials
- The drive pinion and case bearings are typically tapered-roller bearings
- Different forces are generated in the differential due to the action of the pinion gear

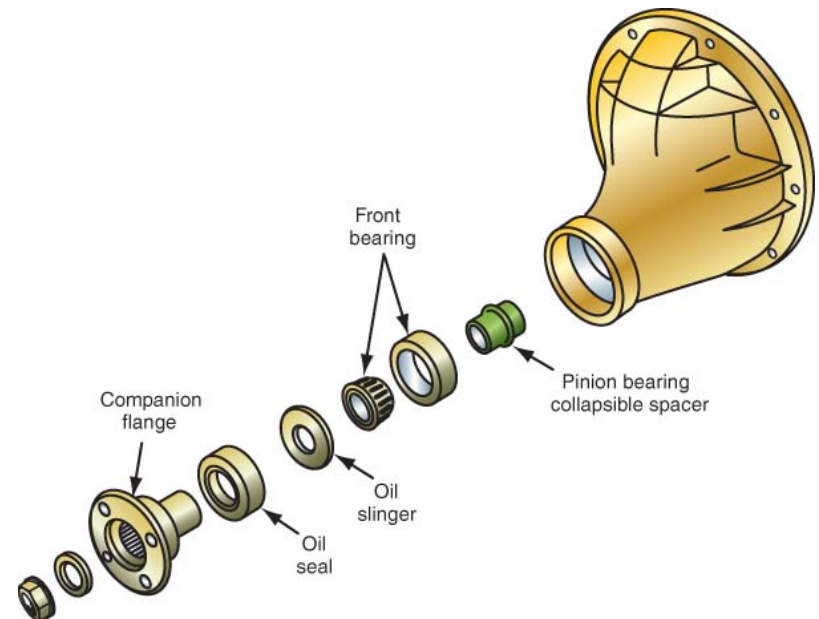
Pinion Mounting Designs

- Straddle-mounted pinion
 - It has two opposing tapered-roller bearings with a spacer between them
 - It also has a straight-roller bearing supporting it
- Overhung-mounted pinion
 - It only has two opposing tapered-roller bearings



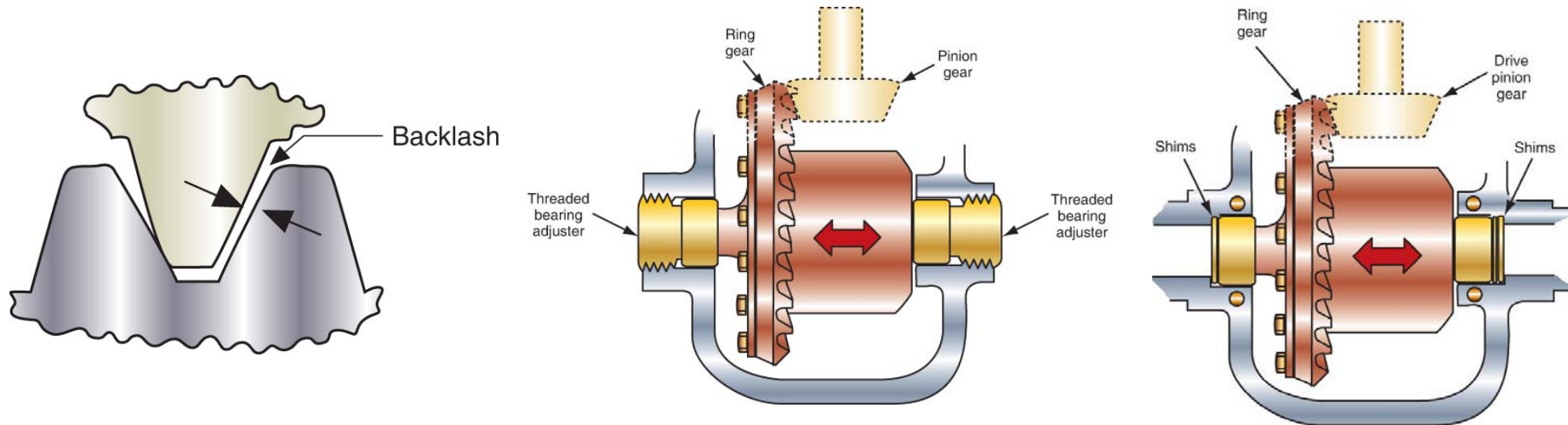
Methods Used to Set Pinion Bearing Preload

- Collapsible spacer method
 - The pinion nut is tightened until the spacer collapses and applies a specific preload to the bearings
- Non-collapsible spacer method
 - Uses selective shims to set the proper preload



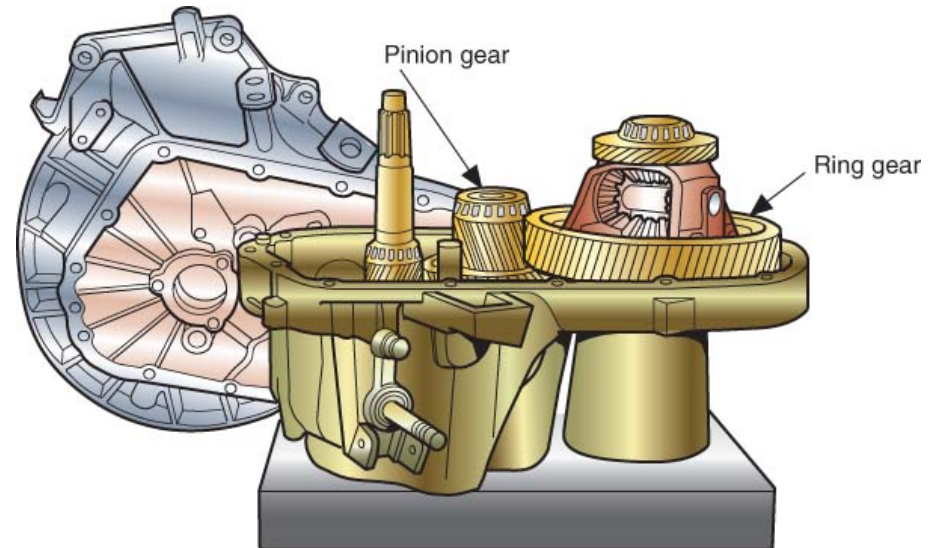
Differential Case Adjustments

- The differential case can be adjusted side to side to provide proper backlash and side bearing preload
- Some designs use threaded bearing adjusters
- Some designs use selective shims and spacers for adjustments



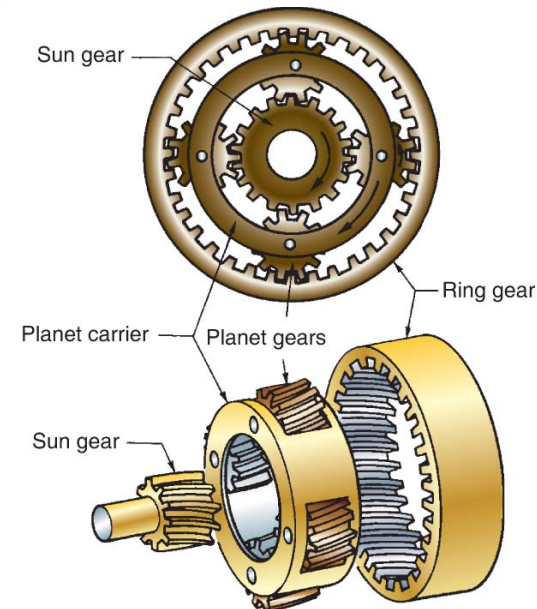
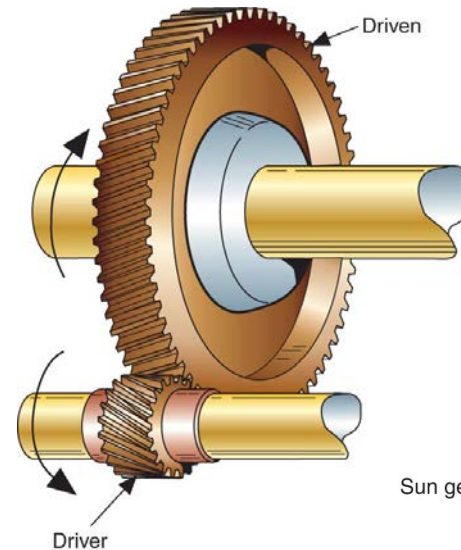
Transaxle Final Drive Features

- The differential operates basically the same as in a RWD axle
- There is no 90-degree change in direction
- The drive pinion is connected to the transmission output shaft
- The ring gear is attached to the differential case



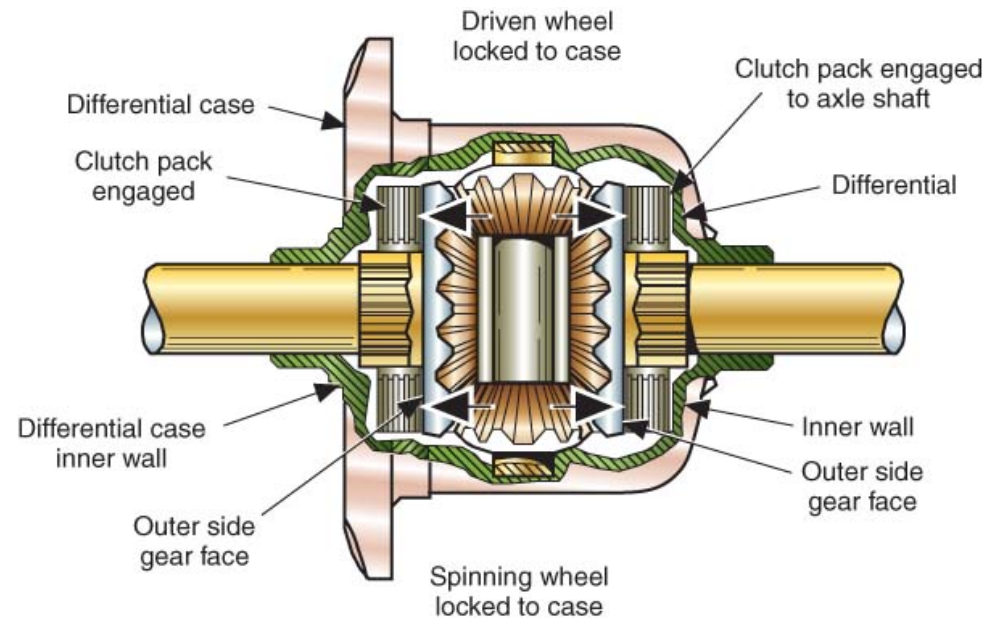
Final Drive Assembly Types

- Helical
 - Requires the centerline of the pinion gear to be aligned with the centerline of the ring gear
- Planetary
 - Allows for a very compact transaxle design
- Hypoid
 - Is quieter and stronger than other designs



Limited-Slip Differentials

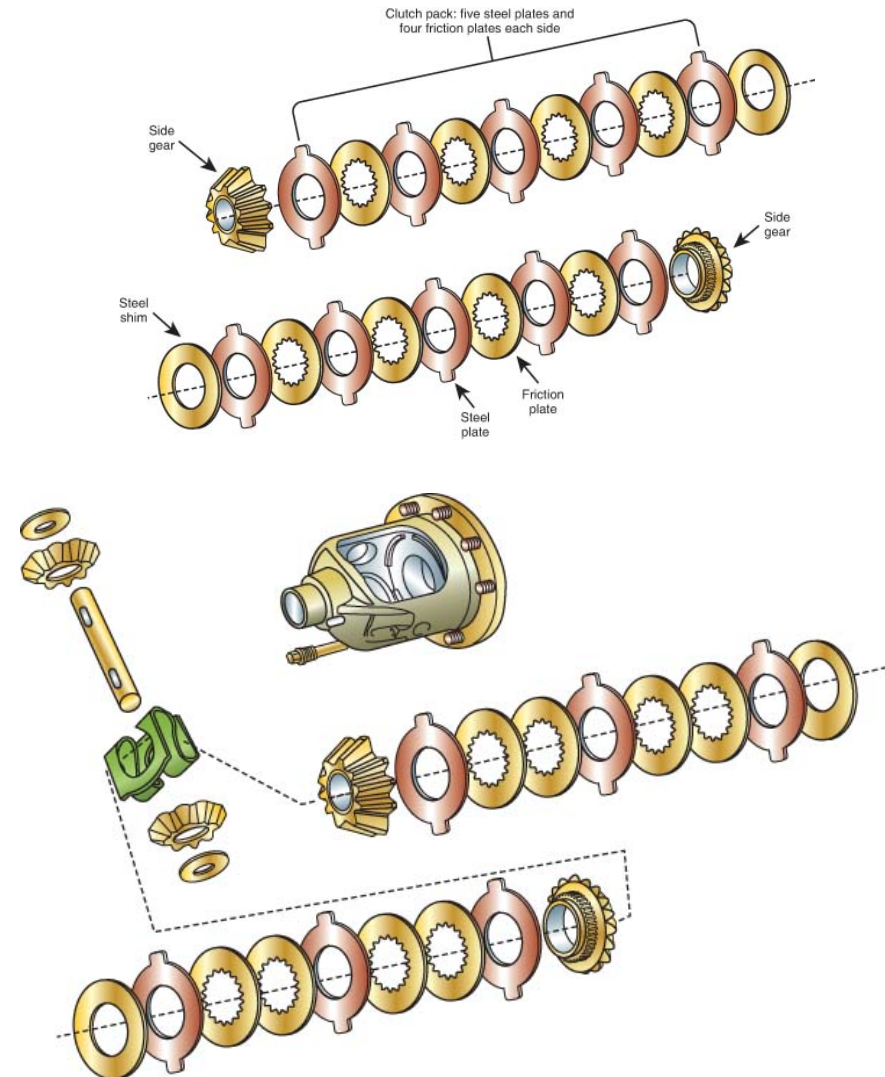
- Provide more driving force to the wheel with traction when one wheel begins to slip
- Still allow the wheels to rotate at different speeds when turning a corner
- Are sometimes called Posi-Traction, Traction-Lok, and Posi-Units



Energized clutches cause locked differential

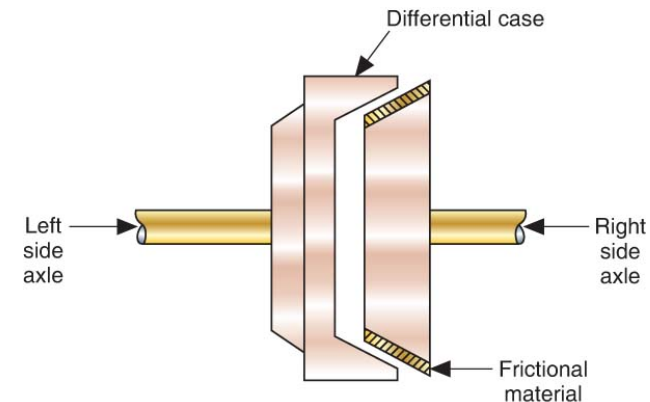
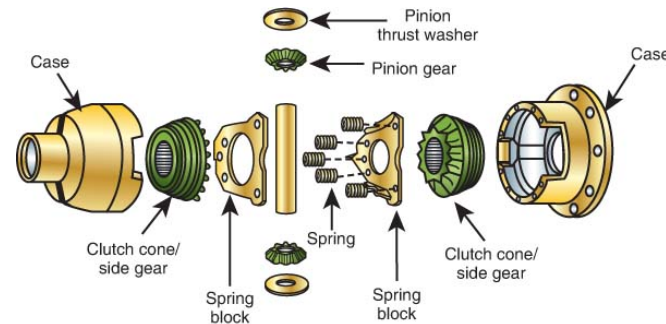
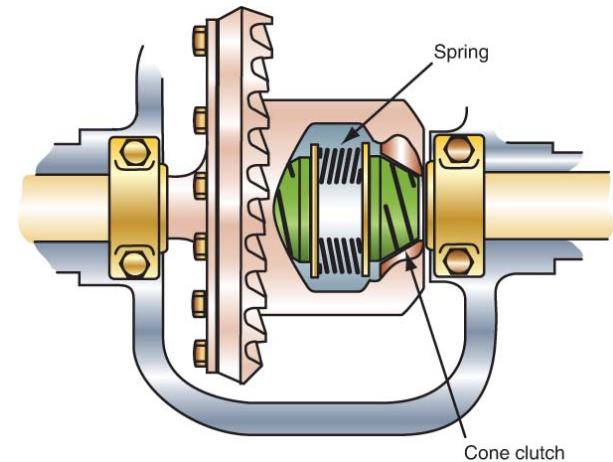
Limited-Slip Differential Designs

- Clutch pack type
 - It uses two sets of clutches, each consisting of steel plates and friction plates
 - The steel plates are splined to the differential case and the friction plates are splined to the side gears
 - During cornering, the plates slip, allowing the wheels to turn at different speeds



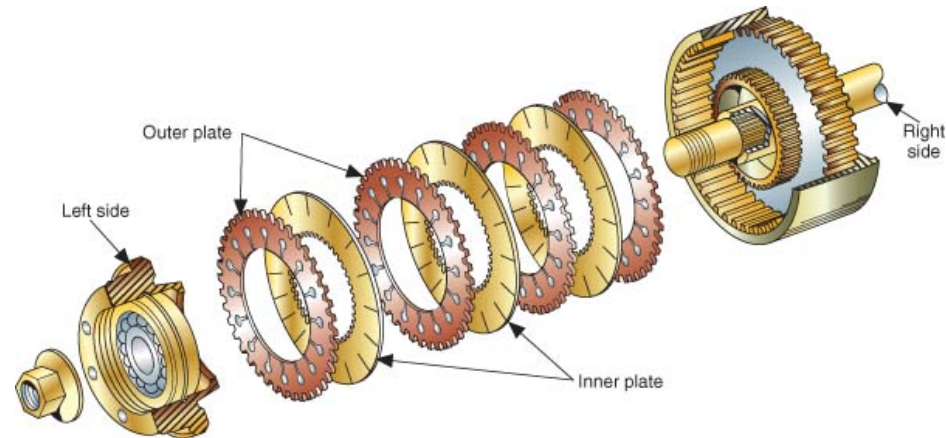
Limited-Slip Differential Designs (*cont'd*)

- Cone-type
 - It uses two cone clutches with one cone that has frictional material on its outer surface and the other with a grooved surface on the inside
 - Cones allow wheels to turn at different speeds during cornering, while providing torque to both wheels during straight-ahead driving



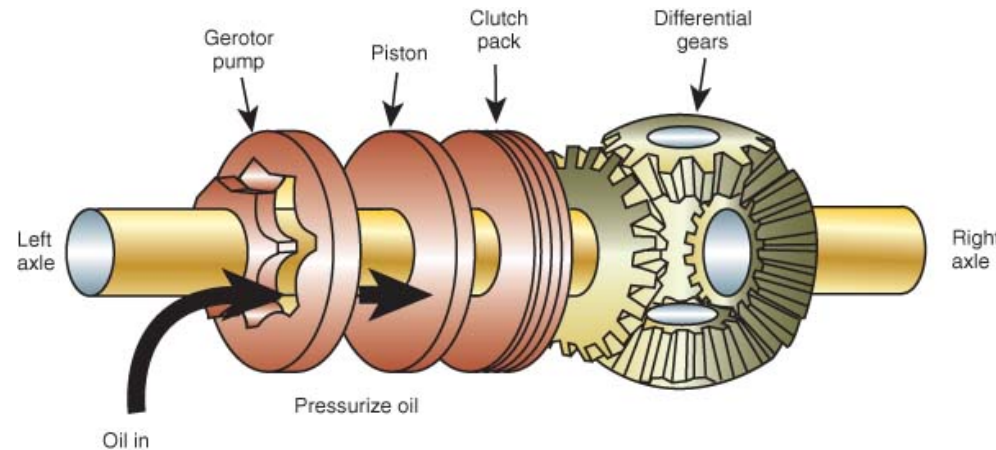
Limited-Slip Differential Designs (*cont'd*)

- Viscous clutch-type
 - It uses steel and frictional clutch plates that rely on the resistance of high-viscosity silicone fluid for application
 - A difference in rotational speed causes the fluid to shear and allows one wheel to turn at a different speed than the other one



Limited-Slip Differential Designs (*cont'd*)

- Gerodisc-type
 - It uses a clutch pack and a hydraulic pump
 - The pump is driven by the left axle shaft
 - The pump's output determines how much pressure is applied to the clutch pack
 - The amount of tire slip determines the pressure delivered by the pump



Limited-Slip Differential Designs (*cont'd*)

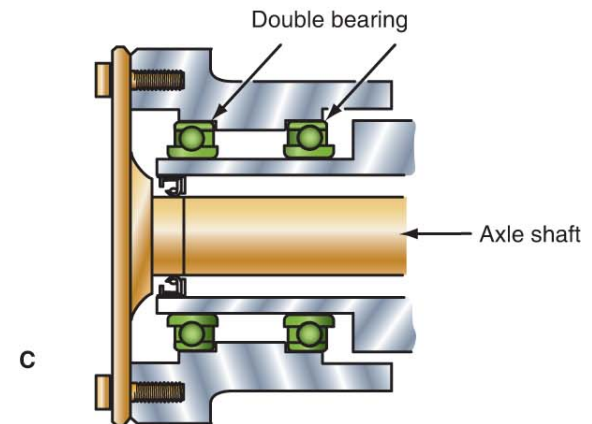
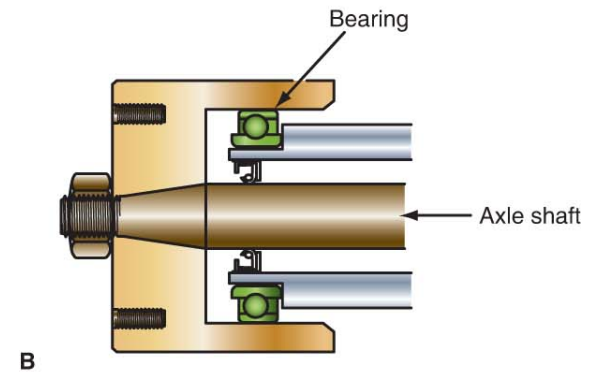
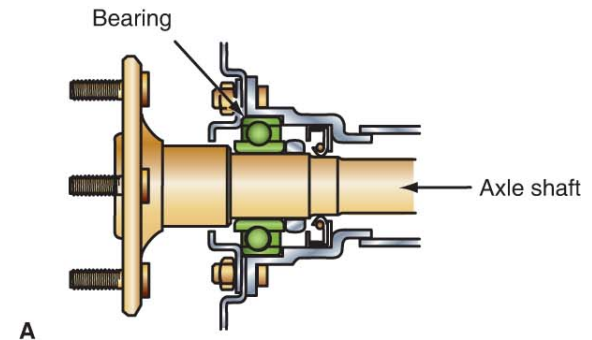
- Electronic
 - Uses speed sensors, antilock brakes, and microcomputers to monitor slipping
 - Can be tuned for specific applications on and off road and at different speeds
- Gear-Based Units
 - Use worm gears that react to change in torque at one of two shafts
 - Torsen
 - QUAIFE Automatic Torque Biasing Differential (ATB)
 - Eaton Detroit Truetrac

Locked Differentials

- Provides very limited differential action, if any
- Designed to provide both drive axles with same amount of torque, regardless of torque
- Detroit Locker
 - Most commonly used
 - Ratcheting-type differential
- Spool
 - Cars built for drag racing and drifting
 - Basically a ring gear mounted to an empty differential case

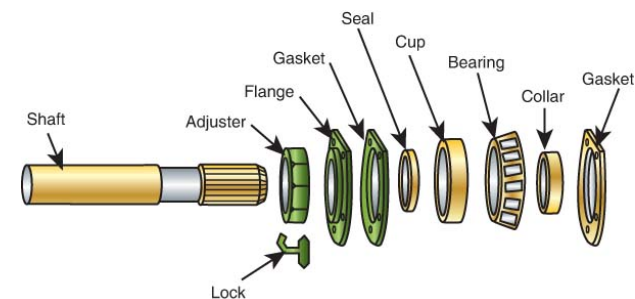
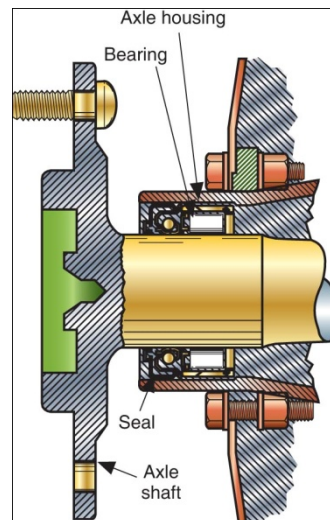
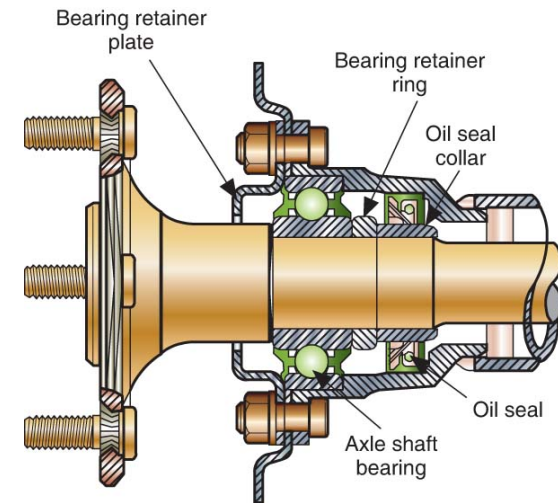
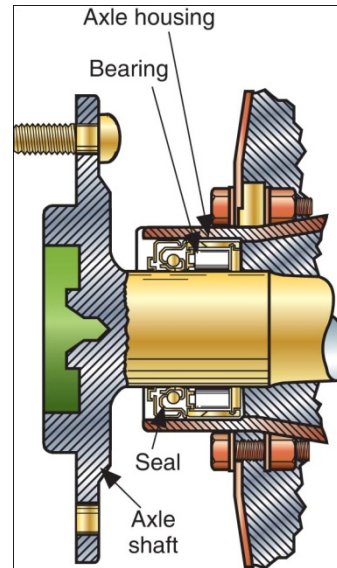
Designs of Axle Bearing Support

- Full-floating axle
 - The bearings are located outside the axle housing
 - They are usually found on heavy-duty applications
- Three-quarter and semi-floating axles
 - The bearings are located inside the housing
 - This design is found on passenger cars and light trucks



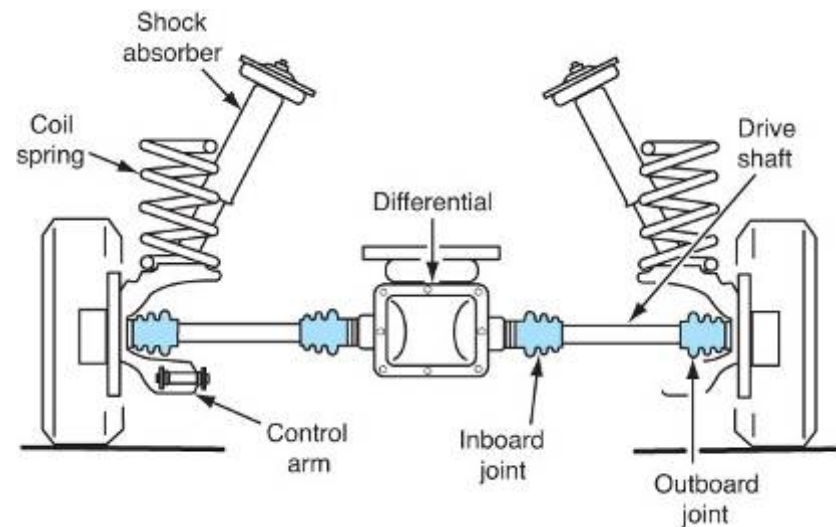
Types of Axle Bearings

- **Ball**
 - Is designed to absorb radial and axial end thrust loads
- **Straight-Roller**
 - Only absorbs radial loads; the axle housing bears the end thrust
- **Tapered-Roller**
 - Axle end thrust can be adjusted



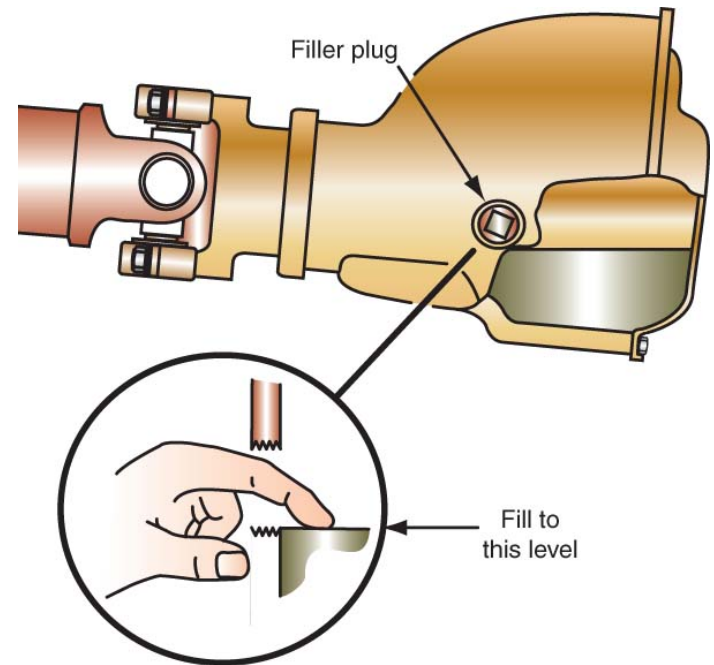
Independent Rear Suspension Design Features

- The differential is bolted to the chassis
- The axles are similar to FWD drive axles
- Each axle has an inner and an outer constant velocity joint



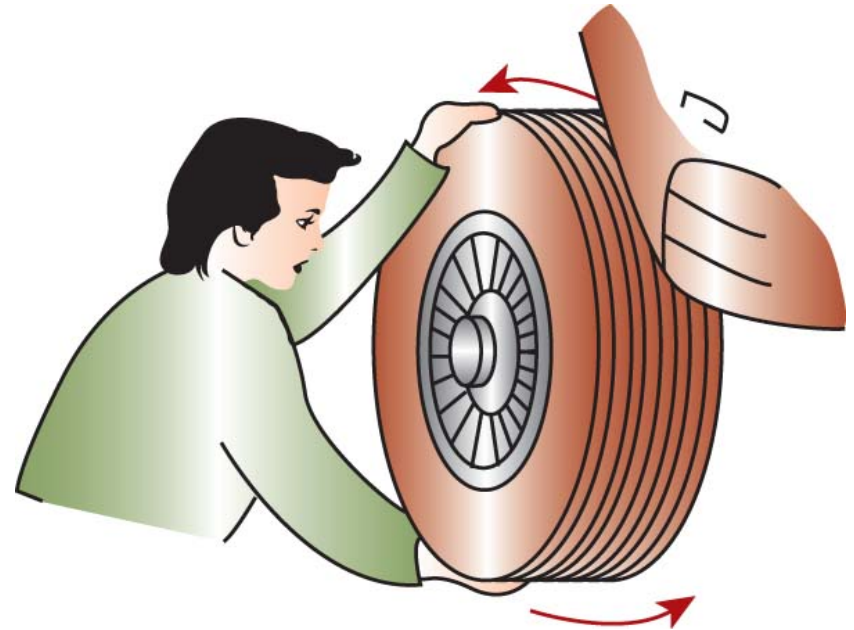
Differential Lubrication

- Hypoid gear types usually use 75W to 90W gear lube
- Limited-slip differentials use a special fluid
- Some applications require ATF
- Some transaxles use a different lubricant for the transmission and the differential



Steps in Differential and Axle Diagnosis

1. Talk to the customer to find out where and when the problem occurs
2. Road test the vehicle, listening and feeling for anything unusual
3. Inspect the vehicle



Questions to Ask the Customer

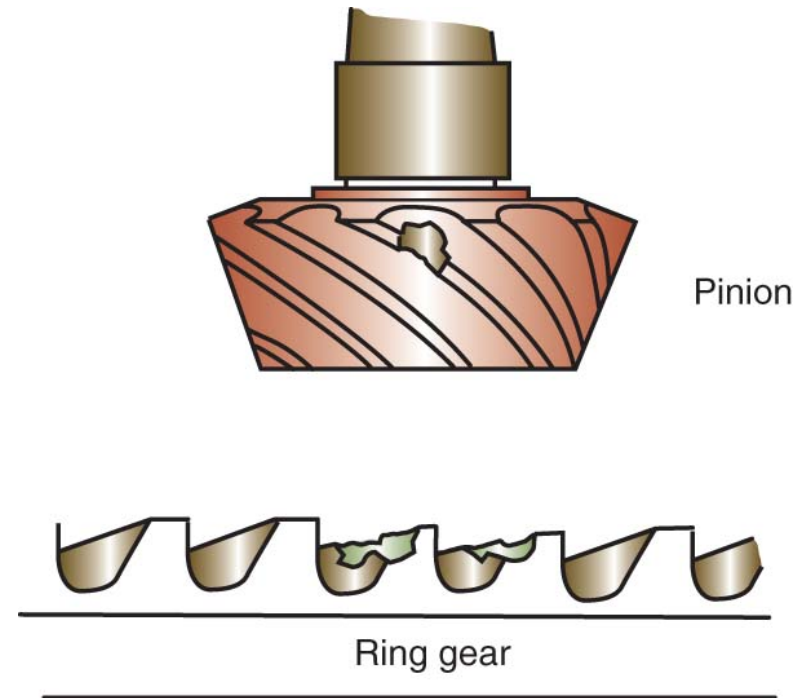
- Ask the customer to carefully describe the problem, including any noises or vibrations
- Ask when and where the problem first occurred
- Ask about the accident and service history of the vehicle

What to Do on a Road Test

- Try to operate the vehicle under the same conditions that the customer described
- Operate the vehicle under these conditions:
 - Drive
 - Coast
 - Cruise
 - Float

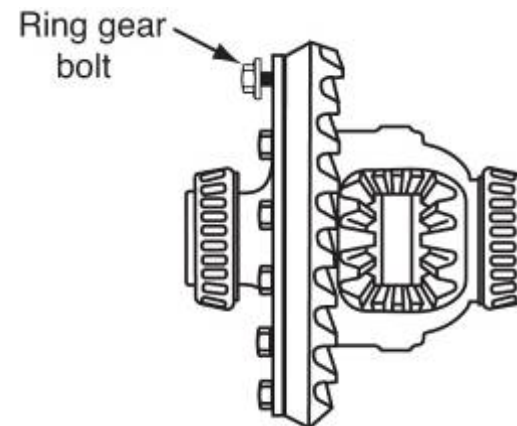
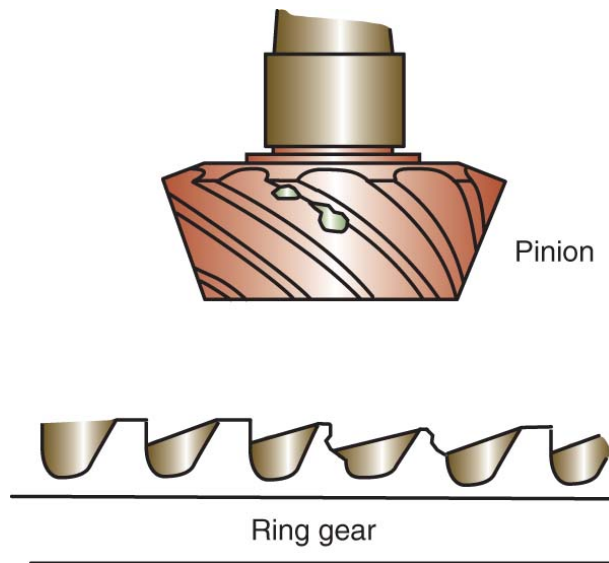
Noise Definitions

- “Chuckle”
 - A rattling noise that sounds like a stick in the spokes of a bicycle wheel
 - It is normally heard during coasting
 - Its frequency will change with vehicle speed
 - It is usually caused by damaged gear teeth



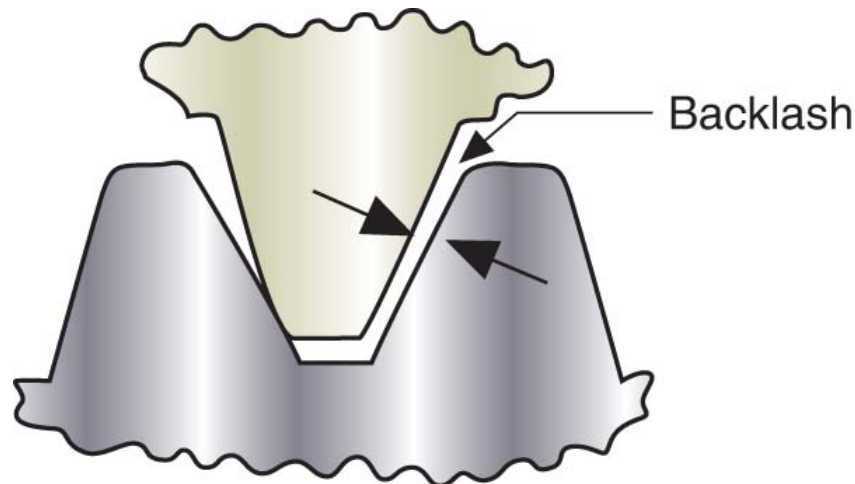
Noise Definitions (*cont'd*)

- “Knocking”
 - Sounds similar to chuckle, but is usually louder
 - Can occur in all driving phases
 - Is usually caused by gear tooth damage on the drive side or loose ring gear bolts



Noise Definitions (*cont'd*)

- “Clunk”
 - A metallic noise often heard when an automatic transmission is shifted into drive or reverse
 - May be heard when the throttle is applied or released
 - Is usually caused by excessive backlash somewhere in the drive line



Noise Definitions (*cont'd*)

- “Gear Noise”
 - The howling or whining of a ring gear and pinion
 - Can occur under various conditions and speeds
 - Is usually caused by an improperly set gear pattern, gear damage, or improper bearing preload

Noise Definitions (*cont'd*)

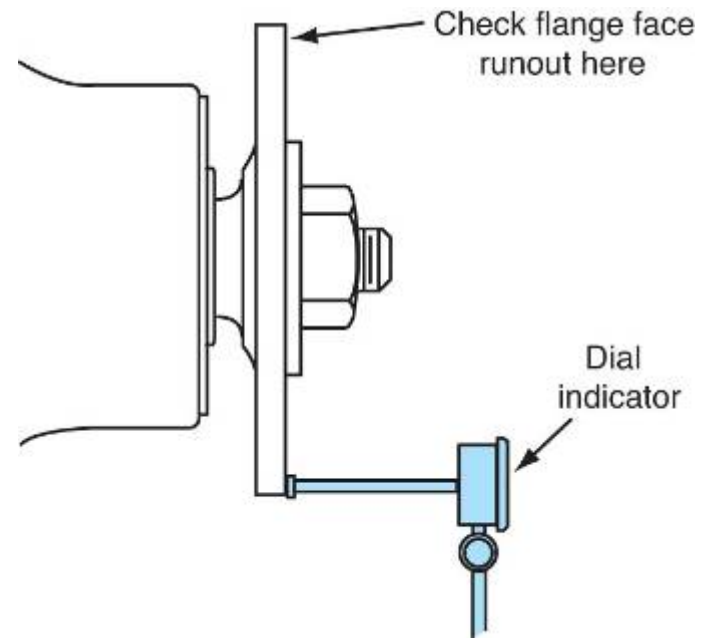
- Bearing “rumble”
 - Sounds like marbles rolling around in a container
 - Is usually caused by a faulty wheel bearing
- Bearing “whine”
 - A high-pitched, whistling noise
 - Is usually caused by faulty pinion bearings

Noise Definitions (*cont'd*)

- “Chatter”
 - Can be felt as well as heard
 - Is usually caused by excessive preload
 - On limited-slip differentials, it is caused by using the wrong type of lubricant

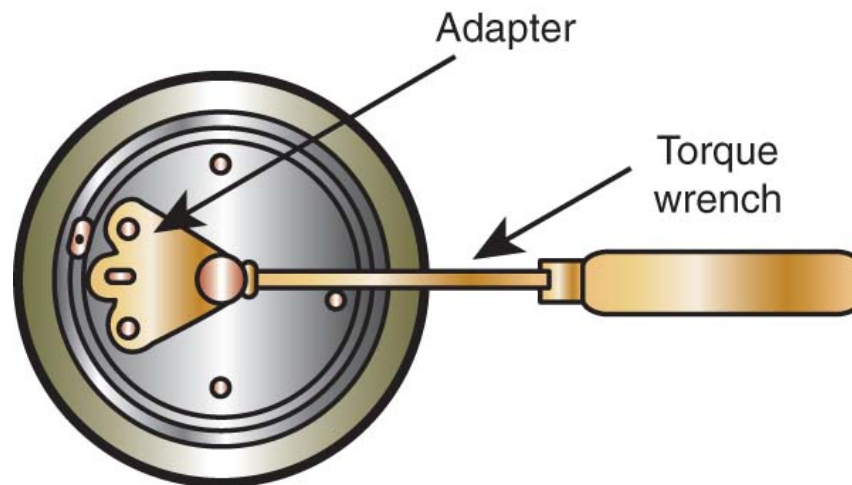
Some Causes of Vibrations

- Out-of-round or imbalanced tires
- Improper drive line angles
- Faulty universal joint
- Bent drive pinion shaft
- Damaged pinion flange



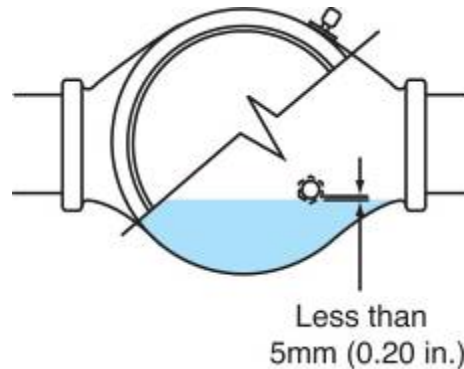
Diagnosing Limited-Slip Concerns

1. Locate the specification for break-away torque
2. With one wheel on the floor and the other one raised, use a torque wrench to check the torque required to turn the wheel
3. If the torque is less than specified, the differential must be checked



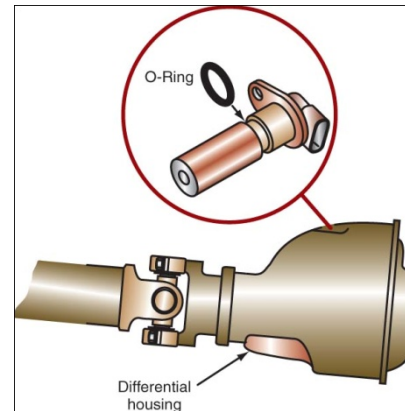
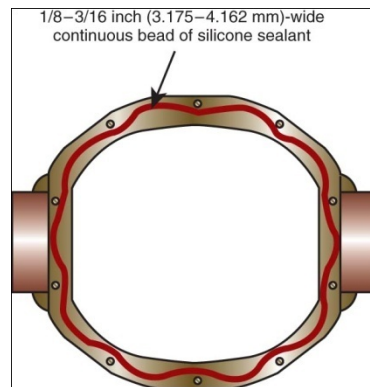
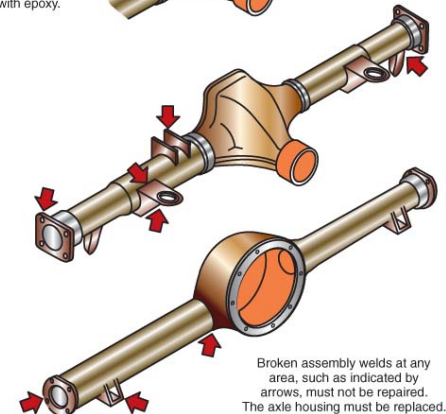
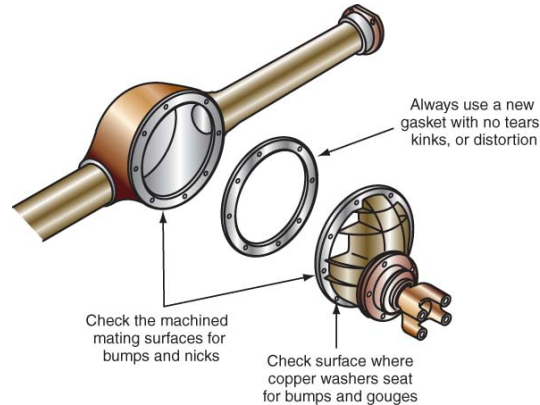
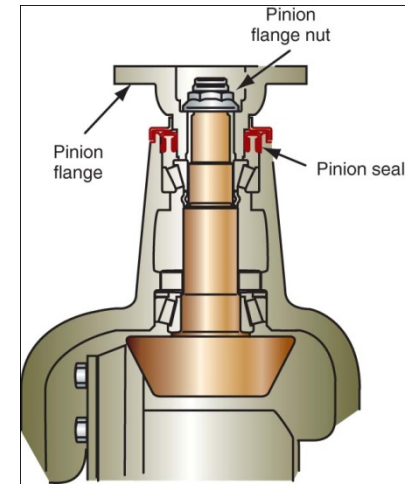
Fluid Level Check

- Make sure the proper fluid is being used
- The vehicle must be level
- The axle assembly must be at normal operating temperature
- The fluid level should be even with the bottom of the fill plug opening



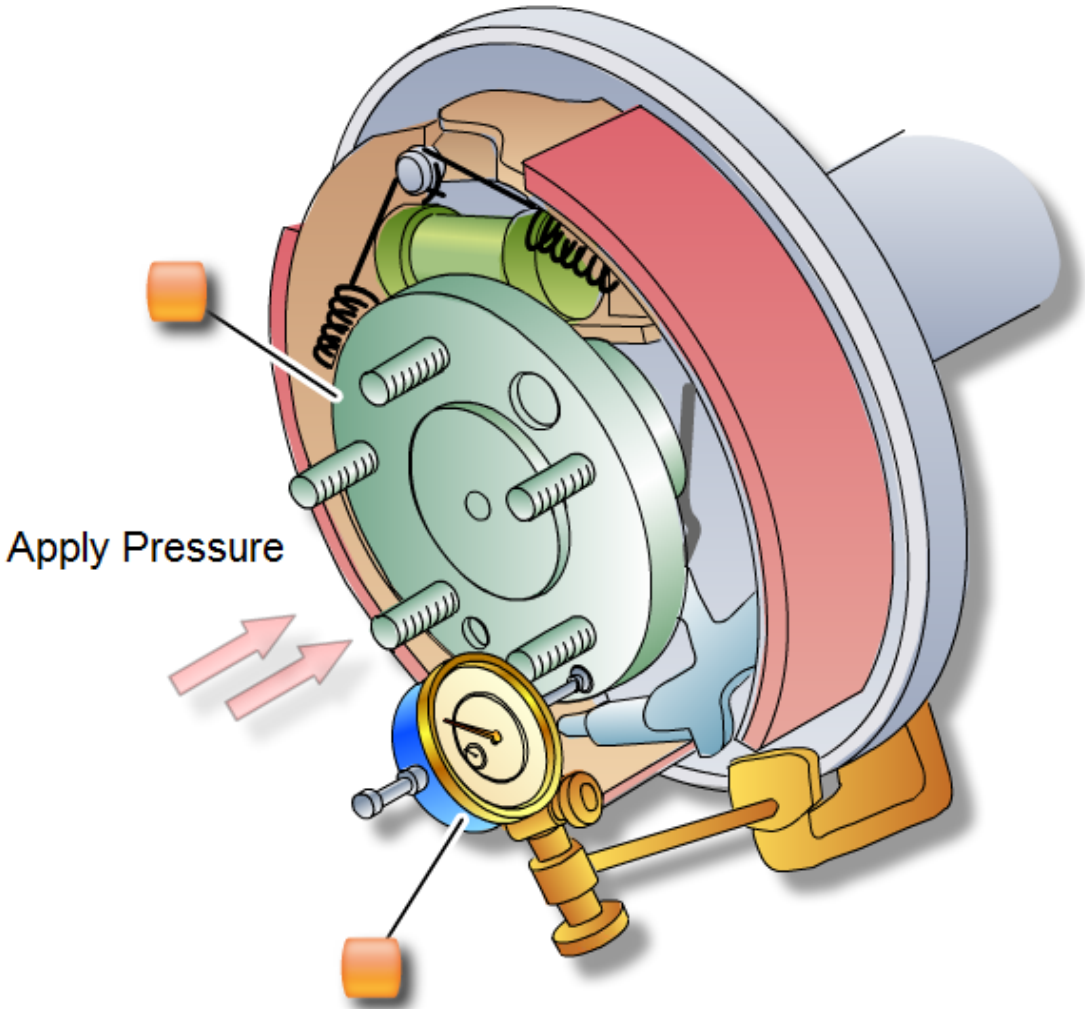
Common Sources of Axle Assembly Leaks

- Damaged pinion seal
- Leakage past the threads of the pinion nut
- Leakage past the carrier assembly stud nuts
- Leaking gaskets
- Housing porosity
- Defective ABS sensor O-ring



Drive Line Inspection

- Position a dial indicator against outer surface of the flange
- Apply slight pressure to the center of the axle to remove axle end play, and zero the indicator
- Slowly rotate the axle one complete turn and observe the readings on the indicator
- Compare the reading with specification
- Inspect wheel studs in the axle flange and threads



To play, click on graphic above

Checking Backlash of the Assembly

- Raise the vehicle on a hoist to free drive wheels
- Clamp a bar between the companion flange and the frame or body so the flange cannot move
- Lower left drive wheel onto a chock, rotate right wheel until it feels like drive condition
- Position a piece of chalk against the tire and turn the tire in the opposite direction
- Length of chalk mark is the total axle backlash and should be 1 inch or less

Checking Backlash of the Assembly (cont'd)

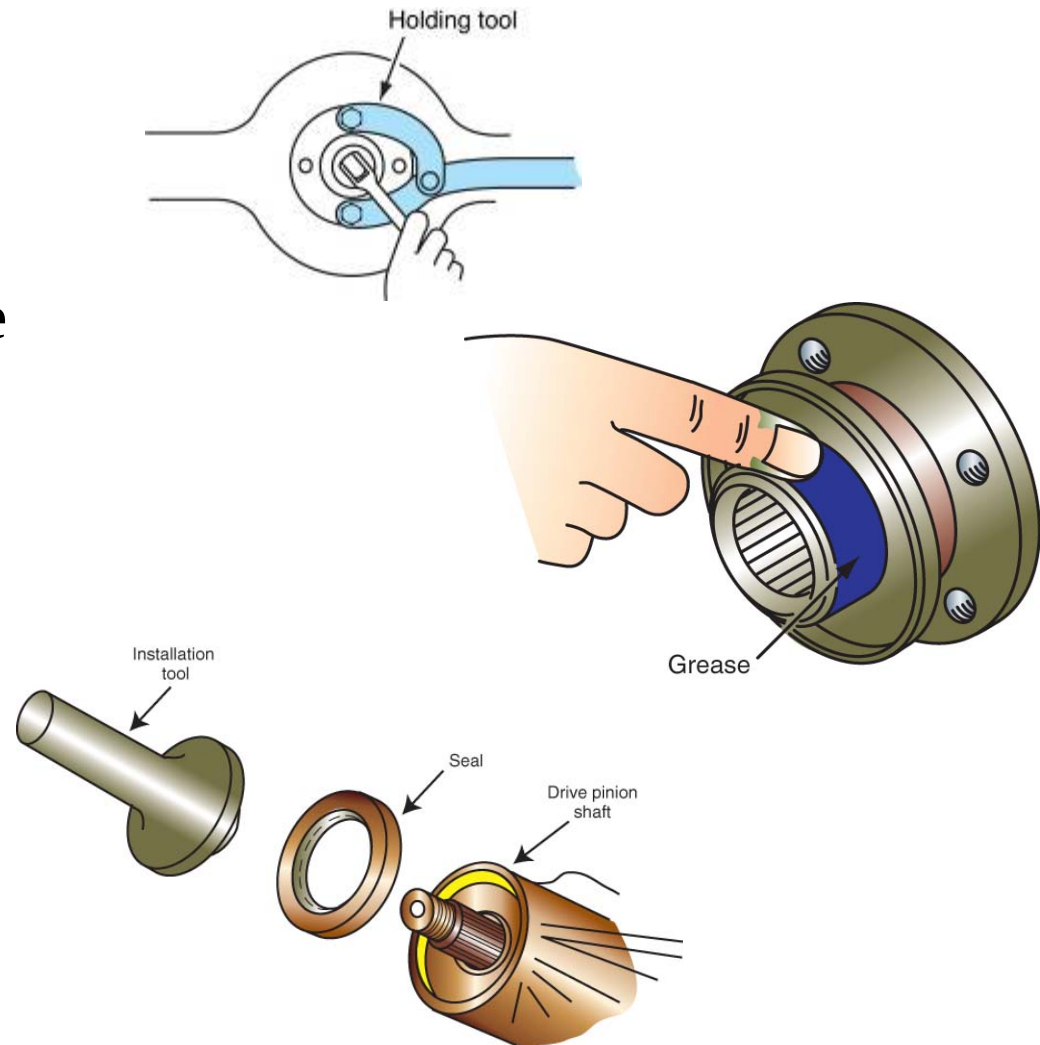
- If backlash is excessive, the following items should be checked:
 - Elongation of the differential pinion shaft holes in the differential case
 - Missing differential or side gear washer
 - Galling of the differential pinion shaft and bore
 - Fit of the axle shafts in the splines of the side gears

Checking Bearing Preload

- Position the vehicle on the frame-contact lift
- Remove rear wheels, brake drums, and drive shaft
- Install an inch-pound torque wrench on the pinion nut and measure the torque required to turn the pinion
- Compare the reading with the specification

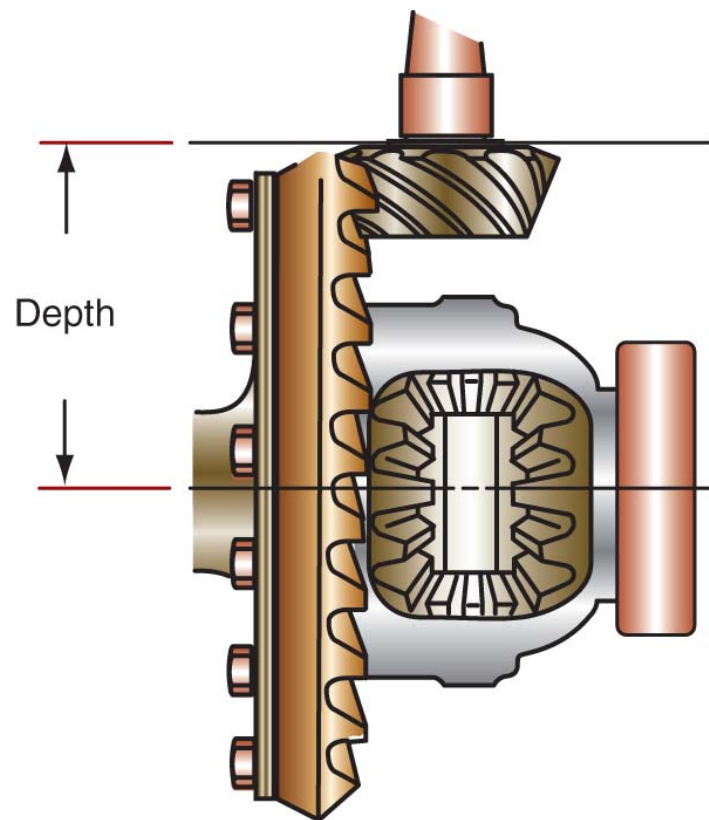
Replacing a Pinion Seal

1. Remove the pinion flange
2. Remove the seal using a slide hammer
3. Lubricate the new seal before installation
4. Use a seal driver to install the new seal
5. Follow the manufacturer's recommendation for tightening the pinion flange nut



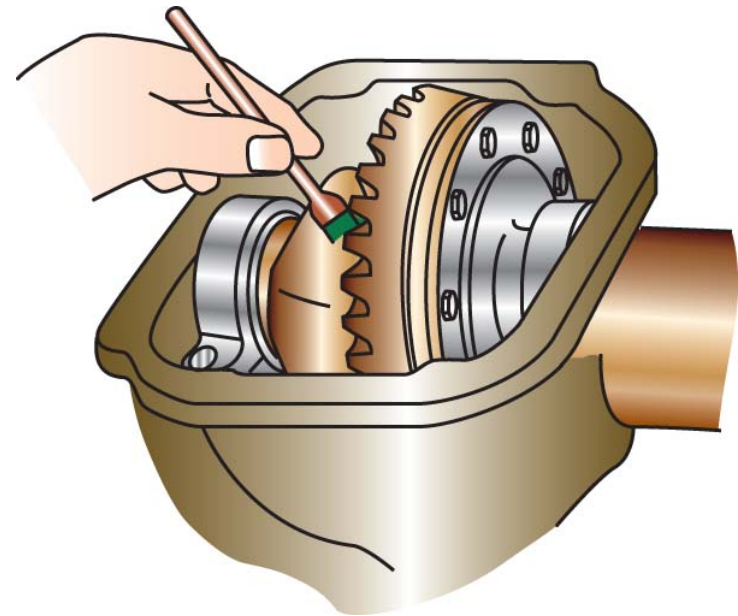
Measuring Ring Gear Runout

1. Mount a dial indicator on the carrier assembly
2. With the stem of the dial indicator on the ring gear, note the highest and lowest readings
3. The difference between the two readings is the ring gear runout



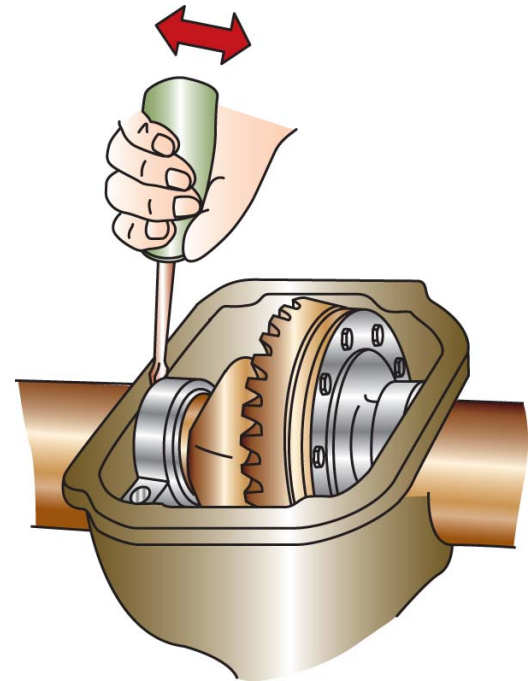
Before Removing Final Drive Assembly

- Check adjustments of ring and pinion gears
- Check the gear tooth pattern
- Measure the pinion bearing preload
- Measure the case bearing preload
- Measure the gear backlash



Carrier Removal and Disassembly Tips

- Always follow shop manual procedures
- Mark the alignment of the drive shaft to the pinion flange before disassembly
- Check the ring and pinion side play before removing

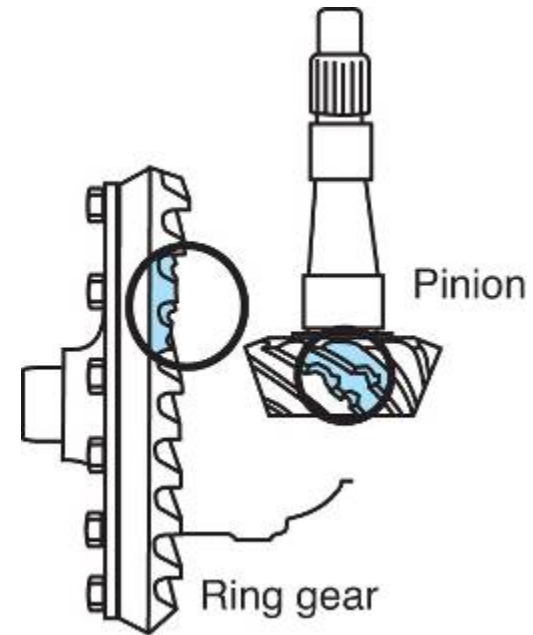


Carrier Removal and Disassembly Tips (*cont'd*)

- Check the ring gear runout before removing
- Keep the shims and bearings in order for reference
- Never reuse the old ring gear bolts

Parts Inspection

- Clean all parts before inspection
- Check the bearings for damage or defects
- Check the gears and gear teeth for cracks, scoring, chips, or damage

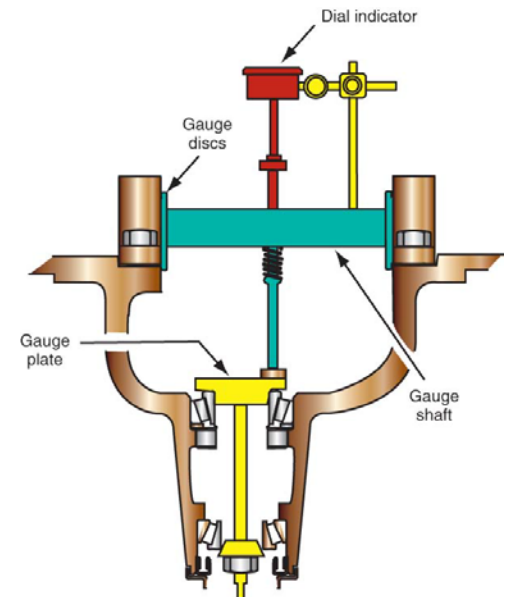
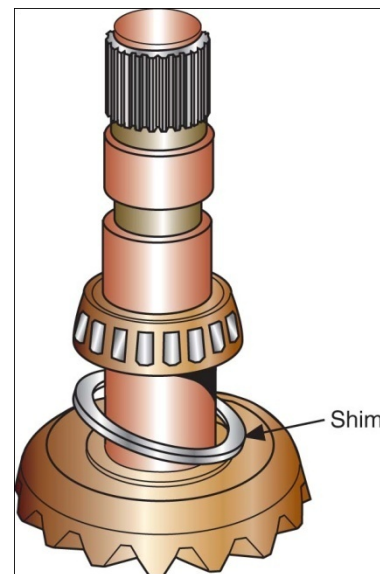
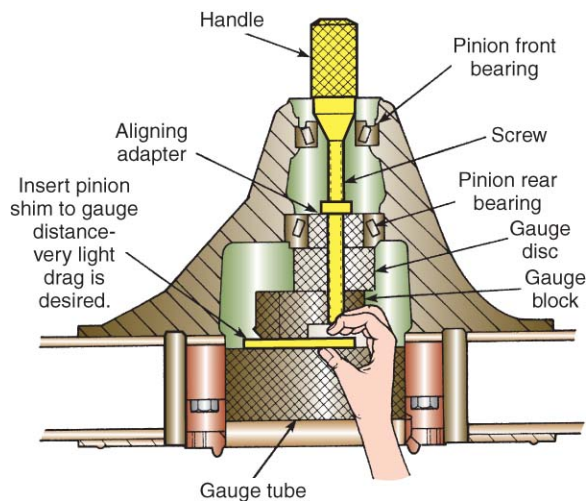
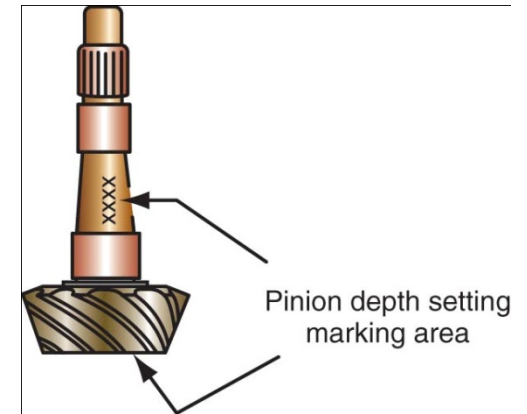
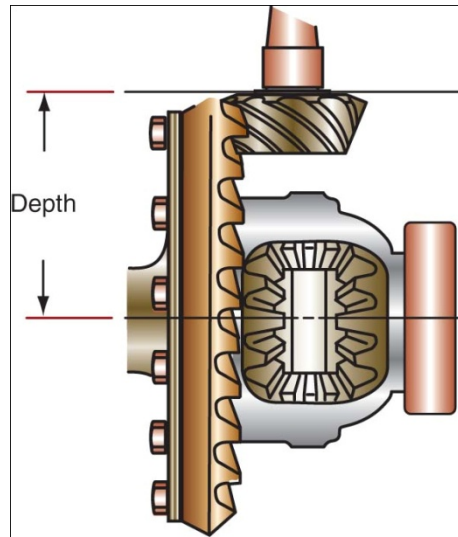


Reassembly Tips

- Always clean the mounting and sealing surfaces before assembly
- Always replace ring and pinion gears in sets
- Use pilot studs to align the ring gear to the case
- Check the gears for timing marks and properly align if necessary

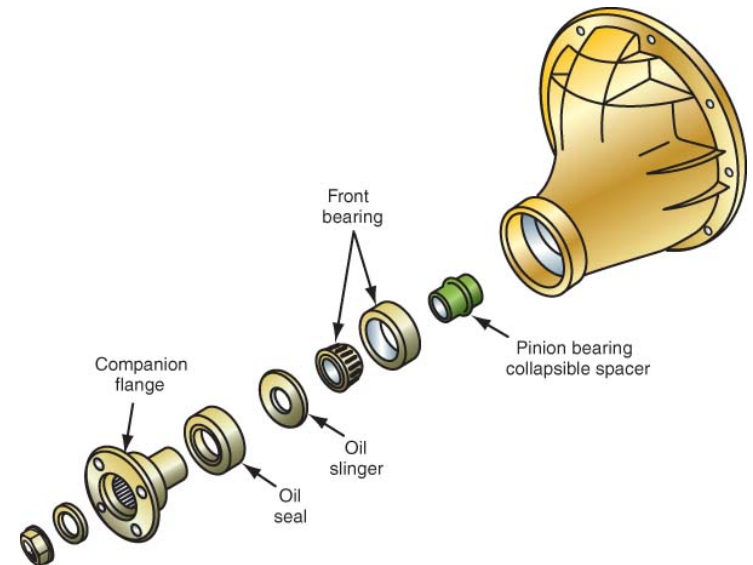
Checking Pinion Gear Depth

- Check the pinion gear for depth adjustment markings
- Use special depth-measuring tools
- Follow service manual instructions



Pinion Bearing Preload

- Check the pinion bearing preload using an inch-pound torque wrench
- Tightening the pinion nut crushes the collapsible spacer to set the preload
- Tighten the nut in small increments, checking preload after each phase
- Take care not to overtighten the nut

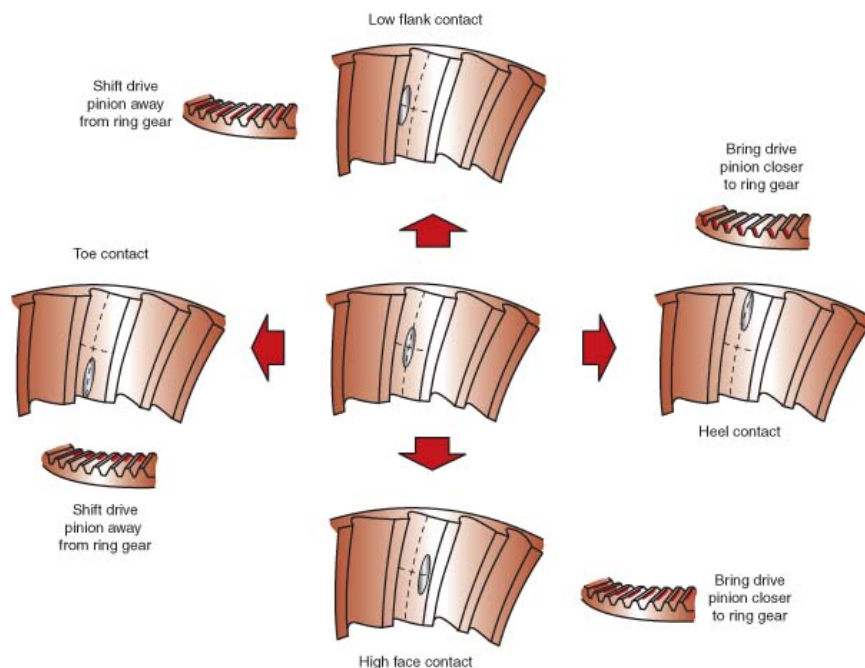


Checking Ring and Pinion Backlash

- Mount the dial indicator base firmly on the axle housing
- Place the dial indicator against the face of a ring gear tooth
- Move the ring gear back and forth and read needle movement
- Take readings at several points around the gear

Gear Tooth Pattern Nomenclature

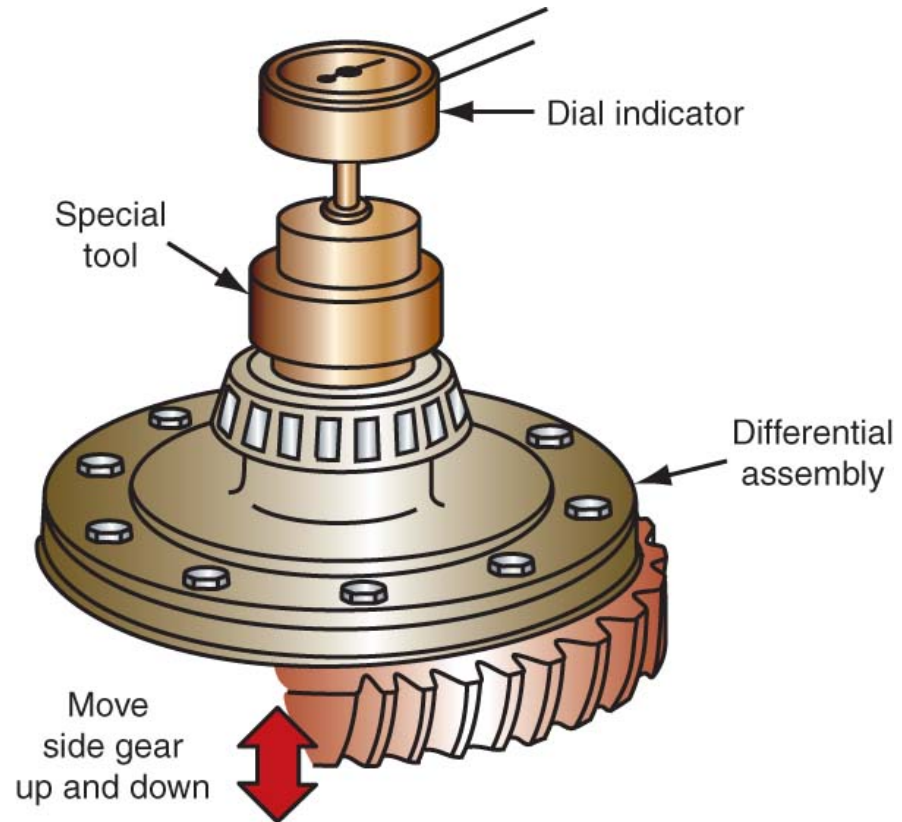
- “Drive”—The convex side of the tooth
- “Coast”—The concave side of the tooth
- “Heel”—The outside diameter of the ring gear
- “Toe”—The inside diameter of the ring gear
- “High”—The area near the top of the tooth
- “Low”—The area near the bottom of the tooth



Heel contact	
Toe contact	
Face contact	
Flank contact	
Correct tooth contact	

FWD Final Drive Service

- Pinion shaft adjustments are not necessary
- Ring gear and side bearing adjustments are necessary
- Adjustments are normally made with the differential case assembled and out of the transaxle
- Always follow service manual procedures

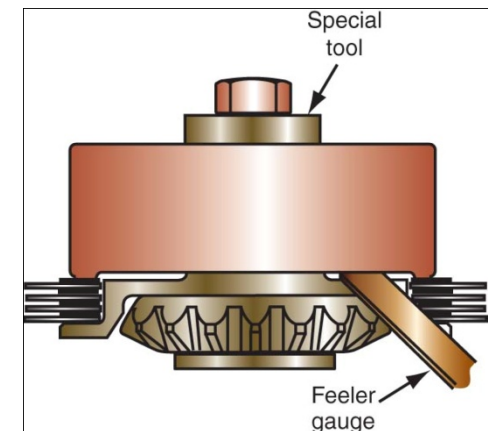
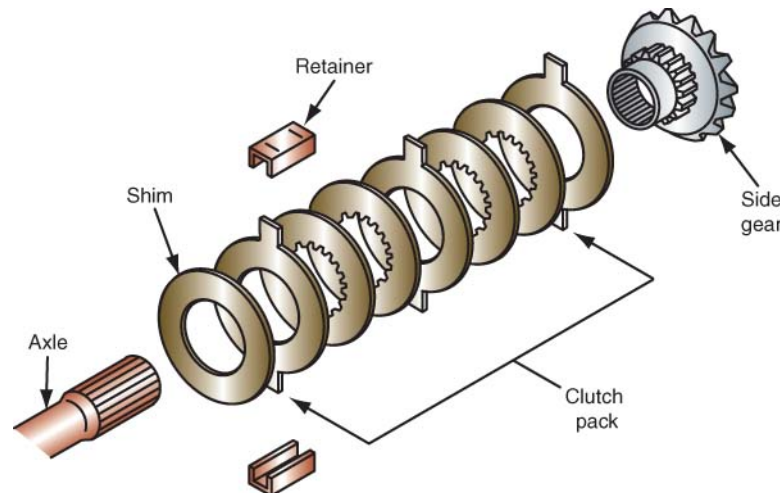
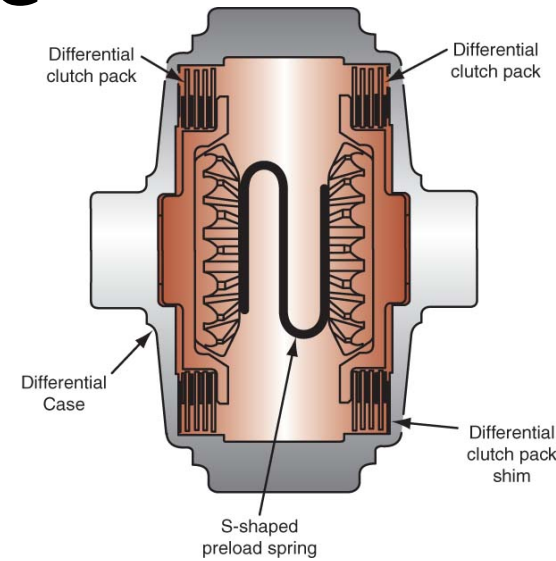
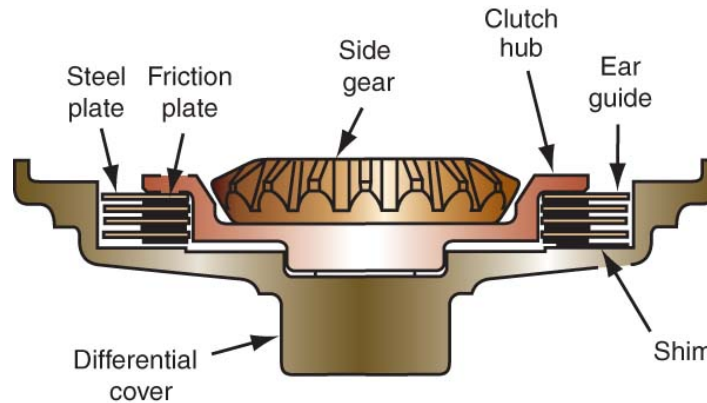


FWD Final Drive Service (*cont'd*)

- Helical
 - Check for worn or chipped teeth, overloaded tapered roller bearings, and excessive differential side gear wear
- Planetary
 - Check for same differential case problems as helical
 - Pay particular attention to the planetary carrier
- Drive Chain
 - Inspect drive chain in some transaxles for side play and stretch

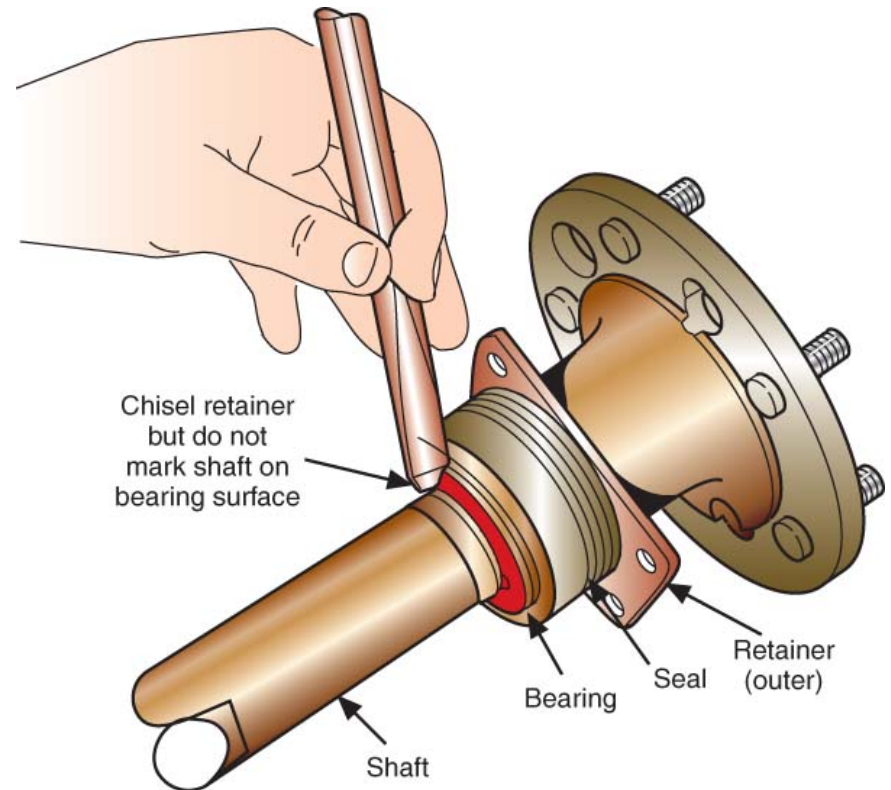
Clutch Type Limited-Slip Differential Service

- Inspect the clutch plates and side gear retainers for wear and cracks
- Refer to the shop manual to determine the proper way to measure thickness
- After assembly, check the total width of the clutch pack to determine shim thickness



Tips for Removing Axle Bearings

- Never use a torch to remove a retaining ring
- Use a drill or cold chisel to loosen a press fit ring
- Use a puller to remove a bearing from an axle housing
- Use a press to remove a tapered bearing from an axle shaft



Bearing Inspection

- Heavily spalled inner race—unacceptable
- Lightly spalled inner race—unacceptable
- Heavy particle indentation and light spalling—unacceptable
- Light particle indentation—acceptable

Summary

- The axle assembly includes the axle housing, ring and pinion gears, differential assembly, and the axles
- A differential allows one wheel to rotate faster than the other in a turn
- The two major designs of axle assemblies are the integral and the removable carrier types

Summary (*cont'd*)

- A limited-slip differential allows torque to be applied to the wheel with the most traction while still allowing the wheels to turn at different speeds while cornering
- Types of gears used as final drive gears are helical, spiral bevel, and hypoid gears
- Three common configurations used as the final drives on FWD vehicles are helical, planetary, and hypoid

Summary (*cont'd*)

- Proper diagnosis of differential and axle problems is important
- Noise or vibration are the common symptoms of differential problems
- Differential measurements include pinion depth, pinion bearing preload, backlash, ring gear runout, and side bearing preload

Summary (*cont'd*)

- Measuring pinion bearing depth requires special tools
- A tooth contact pattern is used to determine needed differential adjustments